

CLAIMS

We claim:

- 1 1. A high-impedance optical electrode used for measuring bio-potentials
2 comprising:
 - 3 a) a light source;
 - 4 b) an electro-optic modulator:
 - 5 (1) receiving light from said light source;
 - 6 (2) modulating said light in response to a bio-potential; and
 - 7 (3) providing a modulated light output proportional to said bio-potential.
- 1 2. The high-impedance optical electrode used for measuring bio-potentials according
2 to claim 1 further comprising a photodetector for receiving and converting said
3 modulated light output from said electro-optic modulator to an electrical signal.
- 1 3. The high-impedance optical electrode used for measuring bio-potentials according
2 to claim 2 further comprising electronic circuitry for providing an electronic output
3 signal.
- 1 4. The high-impedance optical electrode used for measuring bio-potentials according
2 to claim 1 further comprising a pilot tone generated by said electronic circuitry and
3 superimposed on said bio-potential.
- 1 5. The high-impedance optical electrode used for measuring bio-potentials according
2 to claim 1 further comprising an optical splitter for splitting said light from said light
3 source into at least a second light portion.
- 1 6. The high-impedance optical electrode used for measuring bio-potentials according
2 to claim 5 wherein said second light portion is received by a second electro-optical
3 modulator.

1 7. The high-impedance optical electrode used for measuring bio-potentials according
2 to claim 5 wherein said second light portion is used as an optical reference signal.

1 8. The high-impedance optical electrode used for measuring bio-potentials according
2 to claim 1 further comprising an optical phase-shift modulator.

3 9. A high impedance optical electrode for measuring bio-potentials comprising:
4 a) a light source;
5 b) a bio-potential;
6 c) an electro-optic modulator;
7 (1) receiving light from said light source;
8 (2) modulating said light in response to a bio-potential; and
9 (3) providing a modulated light output; and
10 d) a photodetector for receiving and converting said modulated light output from
11 said electro-optic modulator into an electrical output.

1 10. The high impedance optical electrode according to claim 9 wherein said
2 electrical output is a voltage.

1 11. The high impedance optical electrode according to claim 9 wherein said light
2 source is a laser diode.

1 12. The high impedance optical electrode according to claim 11 wherein said laser
2 diode is a highly coherent laser diode.

1 13. The high impedance optical electrode according to claim 11 wherein said laser
2 diode is a low coherent laser diode.

1 14. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 wherein said light source is a distributed feedback laser .

1 15. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 wherein said light source is a Fabry-Perot laser.

1 16. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 wherein said light source is a vertical cavity surface-emitting laser.

1 17. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 wherein said light source is connected to said electro-optic modulator with an
3 optical fiber.

1 18. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 wherein said electro-optic modulator is connected to said photodetector with an
3 optical fiber.

1 19 The high impedance optical electrode for measuring bio-potentials according to
2 claim 17 wherein said electro-optic modulator is connected to said photodetector with
3 an optical fiber.

1 20. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 wherein at least one end of said electro-optic modulator connected to at least
3 one member of a group of members consisting of: an optical fiber, said light source,
4 and said photodetector, is formed at an angle to vertical.

1 21. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 wherein at least one end of said electro-optic modulator is connected to an
3 optical fiber with an optical carrier.

1 22. The high impedance optical electrode for measuring bio-potentials according to
2 claim 21 wherein an end of said optical carrier connected to said electro-optic
3 modulator is formed at an angle to vertical.

1 23. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 wherein at least said electro-optic modulator is enclosed in a housing.

1 24. The high impedance optical electrode for measuring bio-potentials according to
2 claim 23 wherein said housing is hermetically sealed.

1 25 The high impedance optical electrode for measuring bio-potentials according to
2 claim 23 wherein said housing is at least partially covered with electro-magnetic
3 shielding.

1 26. The high impedance optical electrode for measuring bio-potentials according to
2 claim 25 wherein said electro-magnetic shielding is a conductive paint.

1 27. The high impedance optical electrode for measuring bio-potentials according to
2 claim 23 wherein said housing provides a ground return.

1 28. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 wherein said electro-optic modulator is a Mach- Zehnder interferometer.

1 29. The high impedance optical electrode for measuring bio-potentials according to
2 claim 28 wherein said Mach-Zehnder interferometer operates in a linear region.

- 1 30. The high impedance optical electrode for measuring bio-potentials according to
2 claim 28 with said Mach-Zehnder interferometer comprising:
3 a) a substrate having formed therein:
4 (1) a light input wave-guide receiving light from said light source;
5 (2) a splitter connected to said light input wave-guide;
6 (3) a first leg light wave-guide connected to said splitter;
7 (4) a second leg light wave-guide connected to said splitter;
8 (5) a combiner connected for receiving light from said first leg light wave-
9 guide and said second leg light wave-guide; and
10 (6) a light output wave-guide connected to said combiner.

- 1 31. The high impedance optical electrode for measuring bio-potentials according to
2 claim 30 wherein said substrate is crystalline.

- 1 32. The high impedance optical electrode for measuring bio-potentials according to
2 claim 30 wherein said substrate is crystalline.

- 1 33. The high impedance optical electrode for measuring bio-potentials according to
2 claim 30 wherein said crystalline substrate comprises LiNbO_3 .

- 1 34. The high impedance optical electrode for measuring bio-potentials according to
2 claim 30 further comprising:
3 a) a bio-potential plate mounted on said substrate between said first leg light
4 wave-guide and said second light wave-guide;
5 b) a first grounding plate mounted on said substrate on a side of said first leg
6 light wave-guide opposite said bio-potential plate; and
7 c) a second grounding plate mounted on said substrate on a side of said second
8 leg light wave-guide opposite said bio-potential plate.

1 35. The high impedance optical electrode for measuring bio-potentials according to
2 claim 34 wherein said grounding plates are connected to a ground return provided by a
3 housing.

1 36 The high impedance optical electrode for measuring bio-potentials according to
2 claim 34 further comprising a pick-up pad electrically connected to said bio-potential
3 plate.

1 37 The high impedance optical electrode for measuring bio-potentials according to
2 claim 36 further comprising of a shunt resistor connected to said bio-potential plate and
3 said grounding plate.

1 38. The high impedance optical electrode for measuring bio-potentials according to
2 claim 30 wherein a spatial filter is mounted to an end of said substrate.

1 39 The high impedance optical electrode for measuring bio-potentials according to
2 claim 30 further comprising a strap for securing said electro-optic modulator to a
3 patient.

1 40 The high impedance optical electrode for measuring bio-potentials according to
2 claim 30 further comprising a helmet for positioning at least one of said electro-optic
3 modulator on a patient.

1 41. The high impedance optical electrode for measuring bio-potentials according to
2 claim 40 wherein said helmet provides a ground return for said electro-optic modulator.

1 42. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 further comprising a bio-potential plate for receiving said bio-potential and
3 modulating said light in response thereto.

1 43. The high impedance optical electrode for measuring bio-potentials according to
2 claim 42 wherein said bio-potential plate is electrically connected to a pick-up pad for
3 acquiring said bio-potential.

1 44. The high impedance optical electrode for measuring bio-potentials according to
2 claim 43 wherein said pick-up pad is used without conductive ointments.

1 45. The high impedance optical electrode for measuring bio-potentials according to
2 claim 43 wherein said pick-up pad has an irregular surface.

1 46. The high impedance optical electrode for measuring bio-potentials according to
2 claim 43 with said pick-up pad comprising an electrically conducting disk.

1 47. The high impedance optical electrode for measuring bio-potentials according to
2 claim 43 wherein said pick-up pad is mounted to a housing for said electro-optic
3 modulator.

1 48. The high impedance optical electrode for measuring bio-potentials according to
2 claim 42 wherein said bio-potential plate receives said bio-potential through clothing.

1 49. The high impedance optical electrode for measuring bio-potentials according to
2 claim 42 wherein said bio-potential plate receives said bio-potential as a result of
3 capacitive coupling.

1 50. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 further comprising of an optical power splitter for receiving light from said light
3 source and providing said light to at least two light receiving devices.

1 51 The high impedance optical electrode for measuring bio-potentials according to
2 claim 50 wherein one of said light-receiving devices is a second photodetector.

1 52. The high impedance optical electrode for measuring bio-potentials according to
2 claim 51 wherein said second photodetector is a reference photodetector.

1 53. The high impedance optical electrode for measuring bio-potentials according to
2 claim 50 wherein one of said light receiving devices is a second electro-optic
3 modulator.

1 54. The high impedance optical electrode for measuring bio-potentials according to
2 claim 50 wherein said optical splitter comprises an N-splitter.

1 55. The high impedance optical electrode for measuring bio-potentials according to
2 claim 50 wherein said optical splitter comprises an X:Y splitter.

1 56. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 further comprising a phase modulator receiving light from one of the light
3 source and said electro-optic modulator.

1 57. The high impedance optical electrode for measuring bio-potentials according to
2 claim 56 with said phase modulator comprising a piezo-electric substrate having formed
3 therein a light waveguide with a hot electrode and a ground electrode mounted
4 opposite each other on each side of said waveguide.

1 58. The high impedance optical electrode for measuring bio-potentials according to
2 claim 57 further comprising a frequency generator for imposing a potential on said hot
3 electrode with a frequency higher than a frequency range of said bio-potential.

1 59. The high impedance optical electrode for measuring bio-potentials according to
2 claim 9 further comprising electronic circuitry for processing said electrical output from
3 said photodetector.

1 60. The high impedance optical electrode for measuring bio-potentials according to
2 claim 59 with said electronic circuitry comprising post photodetector processing.

1 61. The high impedance optical electrode for measuring bio-potentials according to
2 claim 59 with said electronic circuitry comprising DC transient suppression circuitry.

1 62. The high impedance optical electrode for measuring bio-potentials according to
2 claim 59 with said electronic circuitry comprising amplification circuitry.

1 63. The high impedance optical electrode for measuring bio-potentials according to
2 claim 59 with said electronic circuitry comprising filtering circuitry.

1 64. The high impedance optical electrode for measuring bio-potentials according to
2 claim 59 with said electronic circuitry comprising pilot tone generation circuitry.

1 65. The high impedance optical electrode for measuring bio-potentials according to
2 claim 59 wherein a pilot tone from said pilot tone generation circuitry is superimposed
3 on said bio-potential at a frequency outside of the frequency range of said bio-
4 potential.

1 66. The high impedance optical electrode for measuring bio-potentials according to
2 claim 65 wherein said pilot tone is applied directly to a patient.